

Master Specification

Part ST-SC-C2

Post Tensioned Concrete

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Contents

Contents	3
ST-SC-C2 Post Tensioned Concrete	4
1 General	4
2 Documentation	5
3 Materials	6
4 Tensioning equipment	8
5 Safety	8
6 Tensioning of tendons	8
7 Grouting	12
8 Treatment of anchorages and couplings	16
9 Hold Points and Witness Points	17
10 Verification requirements and records	17

ST-SC-C2 Post Tensioned Concrete

1 General

- a) This Master Specification Part specifies the requirements for the production of post-tensioned prestressed concrete, including:
- i) the documentation requirements, as set out in section 2;
 - ii) the materials requirements, as set out in section 3;
 - iii) the tensioning equipment requirements, as set out in section 4;
 - iv) the safety requirements, as set out in section 5;
 - v) the tensioning of tendons requirements, as set out in section 6;
 - vi) the grouting requirements, as set out in section 7;
 - vii) the treatment of anchorages and couplings requirements, as set out in section 8;
 - viii) the Hold Point and Witness Point requirements, as set out in section 9; and
 - ix) the verification requirements and records, as set out in section 10.
- b) The production of pre-tensioned prestressed concrete must comply with:
- i) the Reference Documents, including:
 - A. AS 1012 Methods of testing concrete;
 - B. AS/NZS 1314 Prestressing anchorages;
 - C. AS 1319 Safety signs for the occupational environment;
 - D. AS 1349 Bourdon tube pressure and vacuum gauges;
 - E. AS 2312 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings;
 - F. AS 3972 General purpose and blended cements;
 - G. AS 4672.1 Steel prestressing materials, Part 1: General requirements;
 - H. AS 4672.2 Steel prestressing materials, Part 2: Testing requirements;
 - I. AS 5100.5 Bridge design, Part 5: Concrete;
 - J. AS/NZS ISO 9001 Quality management systems - Requirements;
 - K. ASTM C940 Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory;
 - L. ASTM C939 Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method); and
 - M. Worksafe Victoria: "Construction and Erection of Bridge Beams" (available from <https://www.worksafe.vic.gov.au/>); and
 - ii) all applicable Laws, including:
 - A. *Work Health and Safety Act (SA) 2012*; and
 - B. *Work Health and Safety Regulations (SA) 2012*.
- c) Prestressed concrete members must be manufactured under a quality system certified to AS/NZS ISO 9001 Quality management systems - Requirements.

- d) All testing and certification required under this Master Specification Part must be carried out by a NATA accredited laboratory.

2 Documentation

2.1 Construction Documentation

In addition to the requirements of PC-CN3 “Construction Management”, the Construction Documentation must include the following documents, procedures, and instructions:

- a) the procedures or safety plans to ensure the safety of all persons during production, including details of no-go zones and protective barriers to prevent injury in the event of equipment failure, including the requirements of section 5a);
- b) where applicable, details of the approved method for stiffening ducts, as required in section 6.2e);
- c) the evidence required for the use of additives in the grout mixture required in section 7.2b);
- d) for precast bridge beams, full details of how the requirements of Section 4 “Manufacture” of the Worksafe Victoria publication: “Construction and Erection of Bridge Beams” will be addressed;
- e) details of the experience of personnel supervising tensioning activities;
- f) in relation to tensioning of tendons, details of:
 - i) the proposed tensioning equipment to be used and proof of its ability to carry out the work;
 - ii) calibration of equipment;
 - iii) the recording of data;
 - iv) the stressing sequence;
 - v) the method of determination of the initial force;
 - vi) the checking for slippage and friction loss;
 - vii) the handling and storage of tendons both in the coiled and made up states; and
 - viii) the safety precautions during tensioning;
- g) in relation to the fabrication and placing of tendons (relating to pre-tensioning), details of:
 - i) the method of ensuring traceability of tendons;
 - ii) the method of placing;
 - iii) the layout of tendons at anchorages;
 - iv) the method of deflecting tendons, if appropriate; and
 - v) the protection against corrosion;
- h) in relation to the method of tensioning tendons (relating to pre-tensioning), details of:
 - i) the sequence of tensioning (for deflected strands);
 - ii) the calculation of forces at anchorages and at member mid points; and
 - iii) the estimated friction losses;
- i) in relation to the method of transfer of prestress (relating to pre-tensioning), details of:
 - i) the release of tendons at end of stressing bed, including sequence of release; and
 - ii) the release of tendons between members;

- j) in relation to the placing of ducts (relating to post-tensioning), details of:
 - i) the method of fixing;
 - ii) the treatment at joints;
 - iii) the temporary stiffening;
 - iv) the grout vents;
 - v) the method of sealing ducts, anchorages, and grout vents; and
 - vi) the method of ensuring ducts and grout vents remain clear of obstructions;
- k) in relation to the assembly of precast segments (relating to post-tensioning), details of:
 - i) the method of supporting segments for jointing;
 - ii) the measures to prevent damage to ducts at joints; and
 - iii) the measures to prevent obstructions occurring the ducts;
- l) in relation to the fabrication and placing of tendons (relating to post-tensioning), details of:
 - i) the method of ensuring traceability of tendons delivered to Site;
 - ii) the method of placing; and
 - iii) the method of corrosion protection; and
- m) in relation to the grouting of tendons (relating to post-tensioning), details of:
 - i) the method of grouting;
 - ii) the mix design, documentation, and testing;
 - iii) the mixing and pumping equipment and evidence of its ability to meet the requirements of this Master Specification Part; and
 - iv) the method of recording quantity of grout usage.

2.2 Quality Management Records

In addition to the requirements of PC-QA1 “Quality Management Requirements” or PC-QA2 “Quality Management Requirements for Major Projects” (as applicable), the Quality Management Records must include the verification records required by Table ST-SC-C2 10-1.

3 Materials

3.1 Tendons

- a) The manufacturer / processor of the tendons must hold a valid certificate of approval issued by the Australasian Certification Authority for Reinforcing and Structural Steels (ACRS), which must be provided as part of the Quality Management Records (refer to: <https://www.acrs.net.au/>).
- b) The Contractor must provide as part of the Quality Management Records:
 - i) details of the composition of the tendons;
 - ii) test results in accordance with AS 4672.2 Steel prestressing materials, Part 2: Testing requirements, demonstrating compliance with AS 4672.1 Steel prestressing materials, Part 1: General requirements; and
 - iii) load-extension graphs covering each coil to be used, taken from 3 representative samples, each 1.4 m long, from each coil.

- c) Evidence of compliance with sections 3.1a) and 3.1b) will constitute a **Hold Point**. Installation of the relevant tendons must not commence until this Hold Point has been released.
- d) Welding is not permitted on or near tendons, nor can any heat be applied to tendons.
- e) Flame cutting of wire or tendon within 75 mm of where the tendon will be gripped by the anchorage or jacks is not permitted.
- f) Tendons which have been affected by welding, weld splatter or heat will be considered a Non-Conformance and the associated Hold Point set out in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable) will apply.

3.2 Anchorages

- a) Anchorages must comply with AS/NZS 1314 Prestressing anchorages. Provision of the test certificates demonstrating compliance will constitute a **Hold Point**. No stressing must occur until the Hold Point has been released.
- b) Spiral or other reinforcement specified by the manufacturer for use in conjunction with anchorage devices must be of the size and dimensions recommended by the manufacturer for the post-tensioning system.
- c) 25 mm minimum diameter grout holes must be provided at both anchorages and must be placed at the highest point of the anchorage. Each of the grouting holes required in this section 3.2c) must be equipped with a plug valve or similar device capable of withstanding a pressure of 1.0 MPa without loss of water, air, or grout.

3.3 Ducts

- a) Ducts must be of a type suitable for the nominated post-tensioning system and must be strong enough to withstand the placing and compaction of the concrete without suffering damage or deformation. The duct and any splices must be sealed to resist the entry of grout.
- b) Steel duct must have a corrugated profile and be galvanized. Plastic duct must be corrugated and have sufficient thickness to resist abrasion during installing and stressing of the tendon.
- c) Enlarged portions of the duct at couplings or anchorages must be of sufficient length to provide for the extension of the tendons. Vents, with plug valves, must be provided at intervals not greater than 10 m along the duct. Additional vents with plug valves must be provided at high and low points in the duct.

3.4 Traceability

- a) Wire, strand, bars and anchorages must be labelled in accordance with the requirements of AS 4672 Steel prestressing materials, or AS/NZS 1314 Prestressing anchorages (as applicable).
- b) Individual lengths of wire, strand or bar must be traceable from the point of manufacture of coils or lots to their final location by a unique identification number. Each coil must be clearly identified by use of a durable metal label to enable matching with the appropriate test certificates and load-extension graphs. Wire or strand not clearly identified in accordance with this section 3.4b) must not be used.
- c) Anchorages must be traceable from the place of manufacture to their final location by a unique identification number.

3.5 Handling, storage and fabrication of materials

- a) Materials must be stored and handled in such a manner so that they are not damaged or contaminated, and their physical properties are not altered, including:
 - i) storage under a waterproof shelter;
 - ii) being supported above ground level; and

- iii) being kept free of all foreign matter on the surface.
- b) Tendons must be free of surface pitting, kinks, and other damage. Ducts must not be damaged or kinked. Anchorage steel components including threads must be protected from corrosion by greased wrappings or plugs until required for use.

4 Tensioning equipment

- a) Dynamometers and each set of equipment comprising, pump, jack, and pressure gauges must be calibrated by a NATA accredited laboratory immediately prior to first use and then at intervals not exceeding 6 months, and the true force at the jack determined from the calibration curve.
- b) Pressure gauges must:
 - i) be concentric scale type gauges complying with AS 1349 Bourdon tube pressure and vacuum gauges;
 - ii) not be less than a nominal size of 150 mm;
 - iii) read between 50% and 80% of its full capacity when the tendon is stressed to 75% of its breaking load; and
 - iv) be fitted with safety devices to protect pressure gauges against sudden release of pressure.
- c) The measuring equipment used must permit tendon force and elongation to be determined to an accuracy of $\pm 2\%$.

5 Safety

- a) The Contractor's safety plans or procedures, included as part of the Construction Documentation, must:
 - i) identify and manage the hazards to:
 - A. site personnel;
 - B. other persons who might be affected by the stressing operation; and
 - C. nearby property; and
 - ii) take the highest standard of care to ensure the safety of all affected persons and property in accordance with the provisions of the *Work Health and Safety Act (SA) 2012* and the *Work Health and Safety Regulations (SA) 2012*.
- b) The Contractor must establish no-go zones with warning signs and substantial barricades in order to provide a protective barrier for site personnel, other persons, and property, and to prevent the entry of unauthorised persons into the hazard zone around and behind the jacking equipment.
- c) Jacking and other site personnel must not be permitted to stand behind the jack or close to the line of the tendons while stressing is in progress. During stressing operations, warning signs that conform to AS 1319 Safety signs for the occupational environment, must be displayed at both ends of the member being tensioned. The stressing jack must be adequately supported and restrained in order to ensure that it cannot cause injury to personnel operating the jacking equipment should the jack lose its grip on the tendons, or should the tendon fail.

6 Tensioning of tendons

6.1 General

- a) The Contractor must provide at least:

- i) 14 days' notice of the day that tensioning will commence, which will constitute a **Witness Point**; and
 - ii) 24 hours' notice of the time that tensioning of each member will commence, which will constitute a **Hold Point**. Tensioning of the relevant member must not commence until this Hold Point has been released.
- b) Tensioning must be performed only by personnel experienced in the tensioning of tendons for post-tensioned concrete. Concrete must not be drilled, or any portion cut or chipped away or otherwise disturbed after prestressing.

6.2 Ducts and grout vents

- a) Ducts, grout vents and their connections must be mortar tight and strong enough to withstand the forces normally encountered in the placing and vibration of concrete and stressing, without suffering any damage or deformation.
- b) Grout vents must be provided at all high and low points in the ducts. Additional vents must be provided beyond each high point in the direction of grout flow at the point where the duct is $\frac{1}{2}$ diameter lower than the high point, but no further than 1 m. Additional vents must also be supplied at the highest point of each anchorage.
- c) Vents must be at least 20 mm in internal diameter and must extend a minimum height of 1 m from the top of the concrete surface. Grout vents must be equipped with a plug valve or similar device, capable of withstanding a pressure of 1 MPa without the loss of air pressure or grout.
- d) Where tendons are installed in ducts after concreting, grout vents must be checked for blockages and cleared, if necessary, at the following times:
 - i) during and immediately after placing of concrete; and
 - ii) prior to installation of tendons.
- e) Ducts in which the permanent tendon will not be in place during concreting must:
 - i) have a temporary tendon inserted; or
 - ii) be stiffened by an approved method set out in the Construction Documentation.

6.3 Couplings

Couplings must be housed such that complete grout encasement of all coupling components will be accomplished during grouting of the tendons.

6.4 Concrete placement

- a) Care must be taken during placing and compaction of concrete to avoid damage to ducts, grout vents, and their connections.
- b) When the permanent tendons are inserted in the ducts before all concreting has been completed, the tendons must be moved backwards and forwards approximately 300 mm after the concrete has hardened, and within 24 hours of placing of concrete, to ensure that the tendons are free to move during tensioning operations.
- c) Where a permanent tendon is not used, and prior to reeving tendons, a wooden or steel dolly must be drawn through the ducts before the concrete hardens to check for obstructions. Any obstructions which may impede the passage or movement of the tendons in the ducts must be removed.

6.5 Placing tendons

- a) Where possible, tendons must not be placed until immediately prior to stressing. When installing tendons, care must be taken to ensure that each strand or wire maintains its relative position with respect to all other strands or wires throughout the length of the tendon.

- b) Where strands are fabricated into a tendon as a group and subsequently pulled through the ducts, the groups of strands or wires must be pulled simultaneously through a comb. When steam curing is used, tendons must not be installed until steam curing is completed.

6.6 Tensioning procedure

- a) Tendons must be checked before tensioning to ensure that they are free to move inside the duct.
- b) Tendon ducts must be cleaned out by blowing oil-free compressed air through them and anchorages must be thoroughly cleaned prior to commencement of tensioning. The protruding ends of tendons must be cleaned of any coating, such as rust, mortar, oil, or mud which would lessen the grip of wedges or anchorage devices. The jack must be set accurately in the line of the tendons.
- c) Prior to the commencement of each post-tensioning operation, a **Hold Point** will apply. The post-tensioning of the relevant tendon must not commence until this Hold Point has been released.
- d) The prestressing force must not be applied to a member until all the concrete in the member has attained the compressive strength shown on the Design Drawings. If a member has been steam cured, the prestressing force must not be applied until the temperature of the concrete has cooled to ambient air temperature.
- e) Once commenced, a tendon stressing operation must be completed without interruption. No tendon can be left in a partially stressed condition. The application and release of the prestressing force must be carried out in such a sequence that produces the minimum of eccentric force in the member.
- f) The tensioning force applied to any tendon must be measured by direct reading of the pressure gauges and checked by comparison of the measured elongation with the elongation calculated by the Contractor from the load-extension graphs supplied.

6.7 Multi-strand tensioning

- a) Anchor blocks must be set parallel to the anchorage prior to any force being applied to the tendon. The force which is applied initially to take up the slack of the tendon must be sufficient to seat the jack firmly but must not exceed the amount normally associated with the particular method of prestressing.
- b) After taking up the slack, individual strands must be accurately marked at both ends so that any slip may be observed. The strands located on the perimeter of the tendon must be used to measure draw-in. Allowance must be made for any draw-in of the tendon at the anchored end.
- c) Where the tendons are required to be tensioned by jacks at each end operating simultaneously, arrangements must be made to keep almost identical forces at each jack throughout the tensioning operation which must continue until the required force in the jacks is reached.

6.8 Monostrand tensioning

- a) All strands must be accurately marked prior to any force being applied to the tendon. An initial force equal to 10% of the final force must be applied to take up the slack of the tendon.
- b) After taking up the slack (as required in section 6.8a), and where applicable, the tendon must be marked at the anchored end so that any slip or draw-in can be measured. Readings of force and elongation must be taken at the initial and final stage of tensioning of each tendon. Elongations must be recorded from the jack ram.
- c) If, during tensioning, the check measurement of any individual strand elongation differs from its required value by +10% or -5%, this will be considered a Non-Conformance and the associated Hold Point set out in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable) will apply. If the

average measured extension of a group of tendons anchored at the same anchorage differs by more than $\pm 7\%$, this will be considered a Non-Conformance and the associated Hold Point set out in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable) will apply.

6.9 Requirements after stressing

- a) The maximum jacking force must not exceed:
 - i) 80% of the rated capacity of the jacking equipment used;
 - ii) 85% of the specified minimum ultimate strength of the tendon; or
 - iii) 75% of the minimum ultimate strength of the bar.
- b) If, during tensioning, the check measurement of elongation differs from its required value by $\pm 7\%$, this will be considered a Non-Conformance and the associated Hold Point set out in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable) will apply. No work in relation to this member can proceed until this Hold Point has been released.
- c) After stressing of a member has been completed, and prior to grouting and cutting back tendons at anchorages, a **Hold Point** will apply. Grouting and cutting back of the relevant tendons at anchorage must not commence until this Hold Point is released.
- d) A precast, post-tensioned member may be lifted from the assembly bed before the stressed tendons have been grouted, provided all ungrouted tendons are marked for measurement of slip, which will constitute a **Hold Point**. Tendons which slip or become damaged will be considered a Non-Conformance and the associated Hold Point set out in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable) will apply. The precast, post-tensioned member must not be lifted from the assembly bed before the stressed tendons have been grouted until the Hold Point has been released.

6.10 Friction loss check

The friction coefficient of the tendons within the ducts must be established as directed or as required on the Design Drawings. The Contractor must have on Site the appropriate equipment to enable the friction loss to be measured between anchorages.

6.11 Tendon failure

- a) Where one or more components or tendons of a group stressed together slips or breaks during stressing operations, a **Hold Point** will apply. No further stressing of the relevant tendons can occur until this Hold Point has been released.
- b) Subject to prior approval as part of the Hold Point in section 6.11 a), a compensating increase in the force of the remaining tendons of the group may be permitted, provided that the jacking force does not exceed 85% of the minimum ultimate tensile strength of the remaining tendons. If this cannot be achieved, the tendon will be considered a Non-Conformance, and the associated Hold Point set out in PC-QA1 "Quality Management Requirements" or PC-QA2 "Quality Management Requirements for Major Projects" (as applicable) will apply.

6.12 Data to be recorded

The following data, where applicable, must be recorded during the stressing process and provided as part of the Quality Management Records:

- a) identification number of each dynamometer, gauge, pump, and jack;
- b) identification particulars of tendons;
- c) initial forces / pressures and elongations;
- d) final forces / pressures and elongations;

- e) elongations obtained at all stages during tensioning, together with corresponding forces / pressures;
- f) elongations and forces / pressures when resetting of jacks is required;
- g) draw-in at both ends of tendons (where applicable);
- h) draw-in of auxiliary wedges at the rear of the jack (where applicable); and
- i) deflection and elastic shortening of the stressed member at the following intervals:
 - i) immediately after stressing; and
 - ii) at 7 and 14 days after stressing.

7 Grouting

7.1 General

- a) For the purpose of this Master Specification Part, corrosivity is as defined in AS 2312 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings.
- b) All cable ducts containing stressed cables must be grouted unless otherwise shown on the Design Drawings. Grouting must be carried out as soon as practical after stressing and in any case no later than:
 - i) one week under high, very high and extreme corrosivity level;
 - ii) 2 weeks under medium corrosivity level; and
 - iii) 3 weeks under low or very low corrosivity level.
- c) The grouting must be carried out in such a manner that the cable ducts are completely filled with a dense and uniform grout. Grouting must not be performed if:
 - i) the air temperature is greater than 29°C when the shade temperature is rising;
 - ii) the air temperature is greater than 32°C when the shade temperature is falling; or
 - iii) the temperature of the concrete is below 10°C or above 30°C.

7.2 Properties of grout

- a) The grout must be a mixture of Type GP Portland cement, in accordance with AS 3972 General purpose and blended cements, and water having a water / cement ratio of not more than 0.40 by mass. Cement and water must conform to the requirements for these materials given in the following Master Specification Parts, except the water must not contain more than 500 mg/L of chloride ions and cement must be less than 21 days old:
 - i) ST-SC-S1 "Normal Class Concrete";
 - ii) ST-SC-S2 "Geopolymer Concrete";
 - iii) ST-SC-S3 "Precast Concrete Units";
 - iv) ST-SC-S4 "Low Pressure Steam Curing of Precast Units";
 - v) ST-SC-S5 "Heat Accelerated Curing";
 - vi) ST-SC-S6 "Steel Reinforcement";
 - vii) ST-SC-S7 "Supply of Concrete";
 - viii) ST-SC-C1 "Pre-Tensioned Concrete";
 - ix) ST-SC-C3 "Fibre Reinforced Polymer Composite Strengthening of Concrete Structures";

- x) ST-SC-C4 “Sprayed Concrete Work”;
 - xi) ST-SC-C6 “Formwork”; and
 - xii) ST-SC-C7 “Placement of Concrete”.
- b) No additives are permitted in the grout mixture unless the Contractor can demonstrate as part of the Construction Documentation that they:
- i) have no harmful effect whatsoever on the prestressing steel;
 - ii) do not contain iron or aluminium powder; and
 - iii) do not generate gases from chemical reaction between grout mix constituents or other materials in contact with the grout.
- c) Grout must have high bleed resistance, low shrinkage, and high fluidity.
- d) Grout must comply with the requirements of Table ST-SC-C2 7-1.

Table ST-SC-C2 7-1 Performance requirements for grout

Property	Test Method	Criteria	Comments	Frequency
Bleeding	ASTM C940 Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory ⁽¹⁾	Final bleeding <0.5%	Measured when 2 successive readings show no further expansion or bleeding	One test per day
Early expansion	ASTM C940 Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory	<2% at 3 hours	Temperature tolerances are 20°C ±5°C	One test per day
Fluidity	ASTM C939 Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method) ⁽²⁾	a) Immediately after mixing: efflux time <20 s b) 45 minutes after mixing: change in efflux time <+3 s	Contractor's target efflux time for the site conditions must not vary from nominated value by <+2 s	One test per day
Minimum compressive strength ⁽³⁾	AS 1012 Methods of testing concrete	32 MPa at 7 days	-	3 cubes per day or lot, whichever is larger

Table notes:

- (1) ASTM C940 Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory, must be modified to simulate wicking of strands as follows:
- cut a 1000 mm long piece of 15.2 mm 7-wire prestressing strand (wrap strand at cuts with suitable tape to prevent splaying the wires when it is cut);
 - degrease and clean the cut strand. Insert the piece of strand vertically and centrally into the grout cylinder using a centraliser and secure in position;
 - introduce the grout into the graduated cylinder as per the test method; and
 - take readings as per the test method.
- (2) ASTM C939 Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method), may be modified as follows:
- fill the flow cone to the top instead of to the standard level; and
 - measure the efflux time as the time measured to fill the one litre container placed directly under the flow cone.
- (3) Additional cubes may be taken if testing is required at other than 7 days.

7.3 Trial mix

- The Contractor must undertake grout trial mixes prior to submission of the relevant Construction Documentation, including the tests listed in Table ST-SC-C2 7-1.
- The Contractor must submit a report outlining details of the grout mix design and all relevant test results (required in section 7.3a) as part of the Quality Management Records, which will constitute a **Hold Point**. The Contractor must not use the relevant grout mix until this Hold Point has been released.

7.4 Air testing of ducts before grouting

- Air testing of ducts before grouting must be carried out under the supervision of the specialist stressing personnel detailed in the Construction Documentation.

- b) Any water in the duct must first be blown out with oil-free air. After sealing the anchorage ends, each duct must be tested as follows:
- i) with all valves closed, pressurise the duct at the inlet with oil-free air to 250 kPa to confirm the installed system has sufficient integrity for grouting;
 - ii) hold the pressure at 250 kPa for 30 seconds. A sudden drop in pressure of more than 100 kPa, or a need to continuously inject compressed air to maintain pressure indicates that the system is not sufficiently sealed for grouting. All leaks must be located and repaired and the test repeated;
 - iii) reduce the pressure to 100 kPa;
 - iv) lock off the air source; and
 - v) record the air pressure loss over time. A pressure loss greater than 40% must not be permitted within a duration of $D = \frac{1.1V+5}{60}$, where:
 - A. D = duration in minutes; and
 - B. V = volume of the duct minus the strand volume, in litres.
- c) If the pressure loss over time, calculated in accordance with section 7.4b)v), is greater than 40%, a thorough inspection and repairs must be undertaken prior to re-testing required by section 7.4b)ii). Where air testing detects leakage between 2 adjacent ducts that cannot be practically rectified, both ducts must be air tested together as a single system and then be grouted simultaneously with 2 lines controlled by individual lock off valves.
- d) If the air loss criterion cannot be achieved after rectifying all detected leakages, an assessment must be undertaken by the specialist stressing personnel who must provide a recommendation whether grouting should proceed.
- e) Provision of conforming test results to demonstrate compliance with this section 7.4 will constitute a **Hold Point**. Grouting of the relevant ducts must not occur until this Hold Point has been released.

7.5 Grouting equipment

- a) The mixing equipment must be of a type capable of producing a uniform suspension of cement in water.
- b) The injection must be capable of continuous operation with minimum variation of pressure and must include a system for recirculating the grout whilst grouting is not in progress.
- c) The grout pump must be capable of delivering grout at a rate of 1800 l/h at pressures up to 1.0 MPa. All piping to the grout pump must have a minimum of bends and valves and changes in diameter. All baffles to the pump must be fitted with 1.18 mm sieve strainers.
- d) The equipment must have sufficient capacity to continuously fill a tendon, without interruption, at the required rate of injection.
- e) During grouting the Contractor must have available adequate flushing-out plant to facilitate complete removal of the grout in the event of a breakdown of the grouting equipment or other disruption before the grouting operation has been completed. This equipment must be ready for operation during grouting.
- f) Piping to the grout pump must have a minimum of bends, valves, and changes in diameter. Pipes and fittings must have a minimum internal diameter of 20 mm.
- g) A standby grout pump must be made available on Site for use at all times during grouting operations. All equipment must be thoroughly washed through with clean water after every series of operations and more frequently if necessary. The intervals between washings must not exceed 3 hours.

7.6 Grout mixing

Water must be added to the mixer first then Portland cement. Mixing must continue for at least 2, but not more than 4, minutes until a uniform consistency is obtained. Only as much grout as may be used in one hour must be mixed in any batch. The Contractor must ensure that each batch of grout is mixed to the same consistency.

7.7 Grout placement

- a) Before grouting, the volume of grout required for each duct must be determined for use as a basis for control of volumes and rates of grout injection. Grout must be injected into the duct from the lowest anchorage in an even continuous flow so that it moves along the duct at a rate of between 6-12 m/min. Filling rates for vertical ducts must not exceed 5 m/min.
- b) When the grout reaches the first grout vent it must be allowed to flow out until all excess water and air has been expelled from the first portion of the duct and it is of the same consistency as the injected grout. This grout vent must then be sealed off and the procedure repeated at the remaining vents until the duct is completely filled. The vents must be progressively closed from the pumping end except that at the intermediate high points the vents immediately downstream must be closed before their associated high point.
- c) In cases where the ducts are longer than 100 m an alternative grouting procedure may be required.
- d) The Contractor must supply attachments suitable for injecting grout at the anchorages and all intermediate grout outlets for use as required if a blockage occurs during grouting. After a period of not less than 2 days, the plugs at grout outlets must be removed and any necessary topping up carried out.
- e) All grout outlet pipes must be cut off or drilled out as necessary to maintain the specified cover to any metal surfaces. The recess so formed must be made good with epoxy to give a smooth surface flush with the concrete.
- f) The Contractor must maintain records of the amount of grout injected into each duct and test results demonstrating compliance with Table ST-SC-C2 7-1.

8 Treatment of anchorages and couplings

- a) Tendons must not be cut back at anchorages until the Hold Point in section 6.9c) has been released. Ends of tendons must be cut with a high-speed abrasive disc or wheel to give the cover as required by AS 5100.5 Bridge design, Part 5; Concrete or as specified in the Design Drawings. Flame cutting of tendons must not be used.
- b) Prior to placing anchorage encasing concrete or concreting an end beam, the roughened end surface of the beams must be coated with an approved wet-to-dry epoxy resin bonding agent.
- c) Anchorage encasing concrete that will be visible in the final condition (such as diaphragms) must be of the same colour as the surrounding concrete. Recesses for stress bars must be concreted within 7 days of grouting.

9 Hold Points and Witness Points

- a) Table ST-SC-C2 9-1 details the review period or notification period, and type (documentation or construction quality) for each Hold Point referred to in this Master Specification Part.
- b) Table ST-SC-C2 9-2 details the review period or notification period, and type (documentation or construction quality) for each Witness Point referred to in this Master Specification Part.

Table ST-SC-C2 9-1 Hold Points

Section reference	Hold Point	Documentation or construction quality	Review period or notification period
3.1c)	Evidence of compliance of tendons	Documentation	10 Business Days review
3.2a)	Test certificates for anchorages	Documentation	10 Business Days review
6.1a)ii)	Notification of tensioning of each member	Construction quality	24 hours notification
6.6c)	Prior to post-tensioning operation	Construction quality	2 hours notification
6.9c)	Prior to grouting and cutting back of tendons	Construction quality	2 hours notification
6.9d)	Marking of ungrouted tendons for measurement of slip	Construction quality	2 hours notification
6.11a)	Failure of components or tendon	Construction quality	2 hours notification
7.3b)	Trial grout mix report and test results	Documentation	5 Business Days review
7.4e)	Air test of ducts results	Construction quality	2 hours notification

Table ST-SC-C2 9-2 Witness Points

Section reference	Hold Point	Documentation or construction quality	Review period or notification period
6.1a)i)	Notification of tensioning	Construction quality	14 days notification

10 Verification requirements and records

The Contractor must supply written verification as part of the Quality Management Records that the requirements listed in Table ST-SC-C2 10-1 have been complied with.

Table ST-SC-C2 10-1 Verification requirements

Section reference	Subject	Record to be provided
3.1a) and 3.1b)	Evidence relating to the tendons	Evidence relating to the tendons required in section 3.1a) and 3.1b)
6.12	Tensioning data records	Records specified in section 6.12
7.3b)	Grout mix design report and all relevant test results	The report and test results required in section 7.3b)